



Biomass: Biofuel Feedstocks

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Session 3D. Bioenergy Crops: The Future is Now

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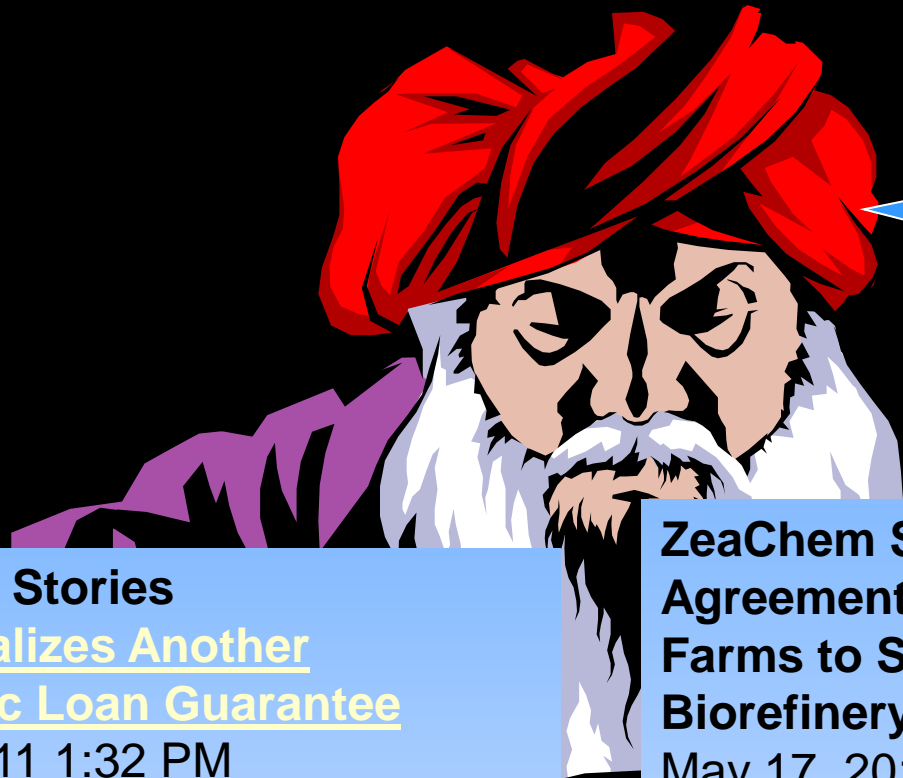
BioEnergy Production

DOE Billion Ton Study Update : key assumptions

By 2030 . . .

- Biomass will displace 30% of US petroleum use
- ~ 1 billion tons of biomass from ag
 - 428 million tons of crop residues
 - 377 million tons perennials
 - 87 million tons of grain
 - 106 million tons of manure
- Corn / small grain yields increased by 1-3% yr
- Residue to grain ratio for soy increased to 2:1
- Removal of 75% of crop residues – Now scaled back to 50%
- 55 million acres of non-farmed land converted to biomass
- Biomass available at \$40-60 / ton – increased from 2005.





Biofuel:
Biomass Availability
And Markets?

Featured Stories

DOE Finalizes Another Cellulosic Loan Guarantee

Oct 4, 2011 1:32 PM

The U.S. Department of Energy (DOE) last week finalized a \$132.4 million loan guarantee to Abengoa Bioenergy to support the development of a commercial-scale cellulosic ethanol plant at Hugoton in southwestern Kansas...

ZeaChem Signs Binding Feedstock Agreement with GreenWood Tree Farms to Supply its First Commercial Biorefinery

May 17, 2011 - ZeaChem Inc., a developer of biorefineries for the conversion of renewable biomass into sustainable fuels and chemicals, today announced it has signed a long-term binding term sheet with GreenWood Tree Farm Fund (GTFF)..... to supply hybrid poplar woody biomass for its first commercial cellulosic biorefinery.....

~ Eight 1st generation plants under construction/operating

Biomass for Cellulosic Ethanol

Dedicated Crops



- Wheat grasses for CRP (2-5 T/A)
- Switchgrasses (15-20 T/A)
- Arundo donax (20-25 T/A)
- Poplar (6-10 T/A)

Crop Residues



**Wheat, barley, grass seed
Corn stover (1-5 T/A)**

Switchgrass



Emergence, June, 2004



2 months, July 28, 2004



12 months May, 2005

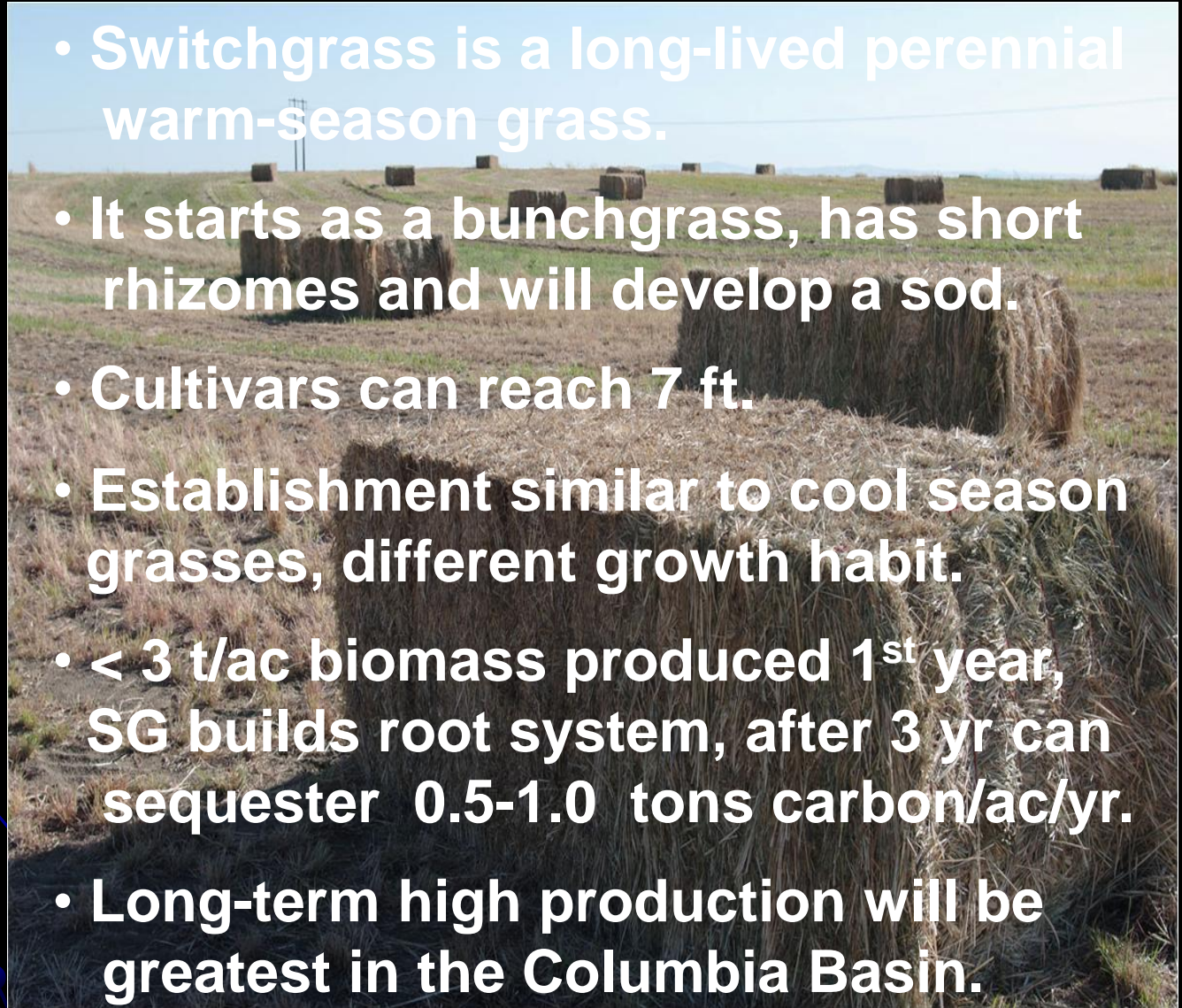


13 months, June 23, 2005



First Harvest: June 24, 2005

- Switchgrass is a long-lived perennial warm-season grass.
- It starts as a bunchgrass, has short rhizomes and will develop a sod.
- Cultivars can reach 7 ft.
- Establishment similar to cool season grasses, different growth habit.
- < 3 t/ac biomass produced 1st year, SG builds root system, after 3 yr can sequester 0.5-1.0 tons carbon/ac/yr.
- Long-term high production will be greatest in the Columbia Basin.



USDA-ARS Field Site, Paterson, WA Switchgrass

Composition

Sample	Part	Soluble +	Hemi	Cellulose	Acid
		others	cellulose		insoluble
		----- % -----			lignin
Switchgrass	Stems+leaves	21.9	27.1	34.2	8.9

2006

***Arundo donax*: Perennial Biomass Plant for Cellulosic Ethanol, Paper Pulp, Thermoenergy**

W. Pan, R. Stevens, T. Peters, K. Borelli, R. Parker



- High yield potential (20-25 T/A/yr by yr 3): higher yields than popular or switchgrass under similar conditions
- High photosynthetic capacity for C3 plant
- Long history of plantation cultivation worldwide for musical reeds, rayon, pulp/paper
- Appears to be pest resistant

Region 3: Irrigated Columbia Basin

Invasiveness Issue

Bad news

- Invasive weed when managed incorrectly: e.g. California planted it in waterways for stream bank erosion control.
- Vegetatively propagates and distributes by water, overtaking the native ecosystems.
- Removal and control costs in these ecosystems are high.

Good news

- Controllable with glyphosate in plantation setting.
- Rhizomes are non-creeping
- Can't survive outside irrigation circle
- Stays vegetative, doesn't make seed that birds, wind might distribute
- Grows well under deficit irrigation

Bottom line: uncontrollable in a water ecosystem;
- controllable in an irrigated system in an arid environment.

Arundo donax:



Composition

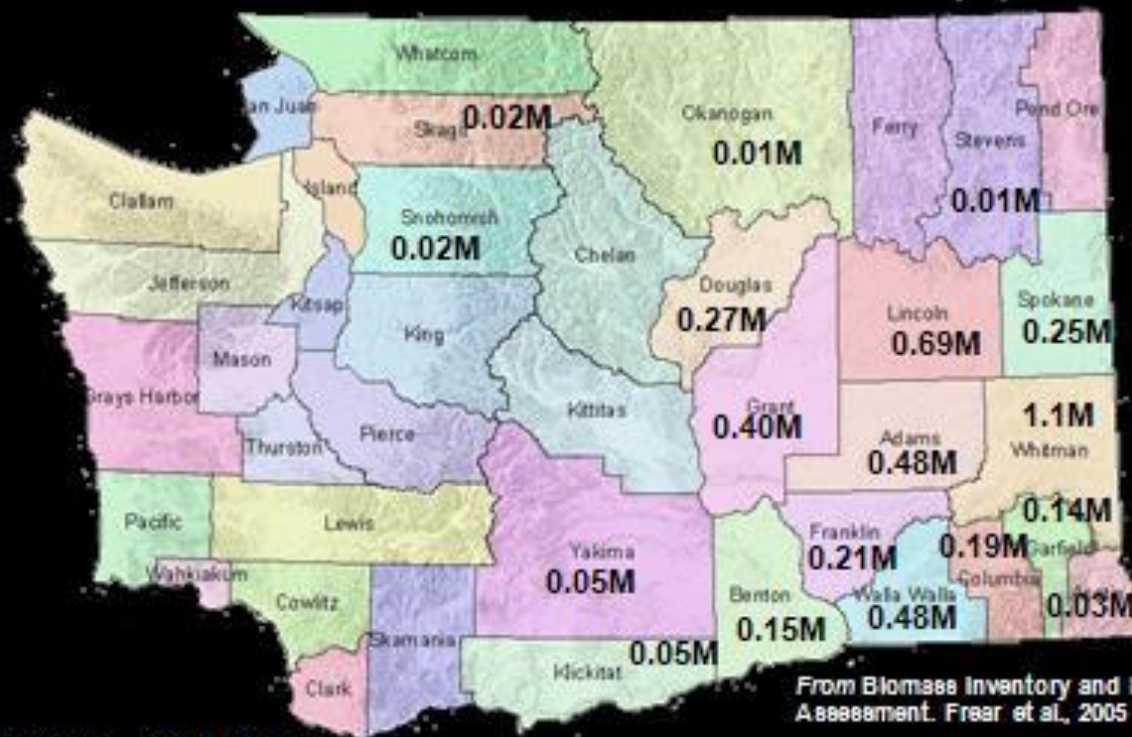
Sample	Part	Soluble +	Hemi	Cellulose	Acid
		others	cellulose		insoluble
		----- % -----			
Switchgrass	Stems+leaves	21.9	27.1	34.2	8.9
Arundo Big	Stems	18.5	13.6	57.0	10.9
	Leaves	36.00	21.1	34.7	8.2
Arundo Small	Stems	23.8	13.3	50.8	12.1
	Leaves	37.6	22.2	31.1	9.0
Wheat Straw		14.4	15.4	59.6	10.6



**Tremendous potential for soil
C sequestration ~6-15 T_{root DM}
/acre/year after 3rd year.**

RESIDUES & BIOFUELS

WA State Residue Inventory



Wheat straw – 6.8 M tons

Barley straw – 1.3 M tons

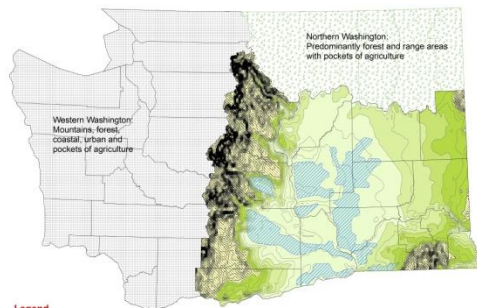
Grass seed straw – 0.5 M tons

> ~50% will be harvested



Wheat Residue Yields

Precipitation	Wheat Yield	Residue Yield
	bu acre ⁻¹	ton acre ⁻¹
Arid Zone (<12 in yr ⁻¹)	15-25	0.7 - 1.1
Low Zone (12-15 in. yr ⁻¹)	25-50	1.1 - 2.3
Medium Zone (15-17 in. yr ⁻¹)	50-75	2.3 - 3.4
High Zone (17-23 in yr ⁻¹)	75-125	3.4 – 6.0
Irrigated Zone	150+	6.0+



Legend
Irrigated Zone*
Eastern WA Precipitation Regions
Arid Zone (<12 in/yr)
Low Zone (12-15 in/yr)
Medium Zone (15-17 in/yr)**
High Zone (17-23 in/yr)**

* Other (Precip >23 in/yr) - Mountains, forests (no agricultural projections)
** Includes substantial areas of dryland rangeland. Any dryland farmland within this general zone is included in E WA dryland precip. zones.
*** Projection regions exclude foothills of Cascade and Blue Mountains where forest and range dominate.

Note: No projections were made for Northern and Western Washington regions because of very limited biofuel crop feedstock potential

Washington State Geographic Regions
for Agricultural Projections

Acres to support a 20M gal ethanol facility.

Precipitation Zone	Residue Yield ton acre⁻¹	†Ethanol Yield gal ac⁻¹	Acres to support a 20 M gal Facility
Arid Zone (<12 in yr ⁻¹)	0.7	56	357,100
Low Zone (12-15 in. yr ⁻¹)	1.1	88	227,300
Medium Zone (15-17 in. yr ⁻¹)	2.3	184	108,700
High Zone (17-23 in yr ⁻¹)	3.4	272	73,500
Irrigated Zone	5.0	400	50,000

†Estimated ethanol yield from wheat straw is 80 gal/ton).

WA State Biomass Markets

- There are a number of companies in WA currently harvesting crop residues for markets
- Annual harvest is ~70 - 120,000 tons of wheat, barley and grass straw. (~12% residue inventory CB)

Current uses:

- Animal feed and bedding
- Mushroom production
- Straw board/composites
- Heating (pellets, co-firing)

Emerging uses:

- Bio-energy production
 - ethanol (ligno-cellulose)
 - pyrolysis/gasification

Hay & Forage Grower: Hay Market Update, 2011

<u>State</u>	<u>Price/ton</u>
Colorado	\$60-75
Idaho	40-65
Kansas	60-75
Montana	25-30
Washington	60-70

Biomass Trials: Wheat, Corn, Switchgrass

Table 4. 2007 Yields: Biomass trials at the USDA-ARS Integrated Cropping Systems Research Field Station, Paterson, WA and estimates of acres needed to support a 20 M gallon ethanol facility.

Crop	Cultivar	Biomass Yield T acre ⁻¹	[†] Ethanol Yield gal ac ⁻¹	Acres support a 20 M gal Facility	€% of Planted Crop Acreage
Wheat (straw)		*5.8	400	£83, 300	51.1
Corn (grain)		*5.6	580	34, 500	28.8
Corn (stover)		6.7	464	£71, 800	59.8
Corn (G+S)		11.3	£1,044	£23, 300	19.4
Switchgrass	Cave'n Rock	9.4	752	26, 600	15.2
	Shawnee	10.3	824	24, 300	13.9
	Kanlow	13.1	1,048	19, 100	10.9

*Yields from wheat and field corn trials were 148 and 200 bu ac⁻¹, respectively. [†]Estimated ethanol yield from wheat straw and corn stover was 69 gal/T, from corn grain was 103 gal/T and switchgrass biomass was 80 gal/T). £Assumes 60% removal of wheat and corn residues. €Percentage of acres needed are based on data reported in the WA. Ag. Stats. for irrigated wheat (WW, SW), field corn and forage (alfalfa/hay).

Production Issues

....."details can mess up good plans".....

Dr. Fulenwilder

- Land Availability
 - Food vs Fuel debate
 - Dedicated crops vs crop residues
 - New strategies – Intercropping systems rather than monocultures
- Water Use
 - Climate change - warming – more water needed
 - Water use efficient crops and cropping systems

Fransen completed study with switchgrass – more efficient than corn
- Development of new harvest and handling technologies
- Storage of biomass
 - quality changes – does it effect efficiency of fuel production
- Nutrient recovery
- Market Competition

Biomass Markets Will be Volatile !

**Because of
Competition for
the Resource**



Source: USGS